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Indian Standard

METHODS OF MEASUREMENT OF RF/MICROWAVE LEAKAGE FROM INTEGRAL CIRCUIT ELECTRON TUBES

UDC 621·385·6·029·5:621·317·3

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INDIAN STANDARDS INSTITUTION
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December 1980

Indian Standard

METHODS OF MEASUREMENT OF RF/MICROWAVE LEAKAGE FROM INTEGRAL CIRCUIT ELECTRON TUBES

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(*Continued on page* 2)

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(*Continued from page* 1)

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Indian Standard

METHODS OF MEASUREMENT OF RF/MICROWAVE LEAKAGE FROM INTEGRAL CIRCUIT ELECTRON TUBES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 11 March 1980, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to specify the methods of measurement of rf/microwave leakage from electron tubes having fully enclosed microwave circuits. Such leakage may occur at leaky rf connectors or at input terminals not normally considered to be part of the microwave circuit. It can also arise because of leakage from inadequate screening or moveable parts of the screening covers, etc.

0.3 While preparing this standard assistance has been derived from the following publications:

> IEC Pub 235-2C(1976) Third supplement to IEC Publication 235-2 (1972) Measurement of electrical properties of microwave tubes, Part II: General measurements. International Electrotechnical Commission.
>
> JSS 51500 (Part II)-1972 Test methods for electron tubes. The Directorate of Standardization, Ministry of Defence, Government of India.

0.4 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS:2-1960*.

1. SCOPE

1.1 This standard deals with methods of measurement of rf/microwave leakage from integral circuit electron tubes.

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*Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.1 For the purpose of this standard, the terms and definitions given in IS: 1885 (Part IV/Sec 3)-1970* and IS: 6134 (Part I)-1978† shall apply.

3. THEORY

3.1 Microwave leakage from integral circuit electron tubes may occur due to inadequacy of the microwave isolation of tube electrode terminals, inadequacy of closure of the microwave circuits themselves and imperfect shielding of the microwave connections associated with input and output circuits. When the tube is operated with grounded anode to obtain consequent reduction in high-voltage hazard, the user may come in such proximity to the tube as to encounter hazard from microwave power leaking from the tube or system. Thus, means for measurement of such leakage power are hereby presented for integral circuit tubes. Electron tubes whose circuits are not integrally contained within the vacuum envelope, namely, planar triodes, external cavity klystrons and coaxial magnetrons with external cavities, may be measured in accordance with the methods prescribed in this standard except that the enclosure as defined in **2.4** of IS: 6134 (Part I)-1978† shall include the external circuits and the connections to the interaction region.

3.2 In the case of more conventional tubes, when the circuit is separate from the tube, it becomes impossible to measure those fields associated with the tube alone; here, the radiation leakage problem is really one of equipment design.

Spurious oscillations may give rise to especially high leakage. For this reason, the measurement of the leakage should be performed in a broad frequency range.

3.3 The measurement of microwave leakage power density can be accomplished with accuracy only if proper consideration is given to:

a) the characteristics of the source;

b) the effect of the presence of the instrument on the source impedance;

c) the perturbation that the instrument introduces in the leakage field, apart from the foregoing effects; and

d) the relative sensitivity of the sensor to the various components of the leakage radiation from the source.

---

*Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes.

†Methods of measurements of electrical characteristics of microwave tubes: Part I Common to all microwave tubes.

3.4 While the source of leakage is not generally a single simple source, it can usually be represented by either a line or a point source or by an arrary of such elements. By reference to the fields emanating from a short dipole, it can be shown that there are two regions of significant interest. The usually important region is called the 'far field', in which the field exists in essentially plane waves. Near the dipole are additional E fields, usually considered important within $\frac{\lambda}{2}$ of the dipole, which are in time quadrature with the principal E field and become very large close to the dipole. This region is called the 'reactive field region' since the largest field component of the region is out of phase with the radiating field. When the leakage source is more complex than may be represented by a simple dipole, a third region of significance is often discussed, called 'the Fresnel region'. The term 'near-field region' is avoided in this standard as it is often applied erroneously to both the Fresnel and reactive regions without distinction. The position of the outer boundary of this region is a function of the aperture of the source and is generally given by:

$$R_s = \frac{2D_s^2}{\lambda}$$

where

R_s = distance to source,

λ = wavelength of the radiation, and

D_s = major dimension of the source aperture.

3.5 When the measuring instrument is placed close to such a leakage source, it may reflect power back into the source to an extent roughly determined by the solid angle that the instrument subtends at the source. Such reflected power perturbs the source impedance in such a way as to increase or decrease the power radiated from the source, depending on phase relationships.

These effects have been found to be negligible when the instrument-to-source distance is greater than R_i in the relation:

$$R_i = \frac{2D_i^2}{\lambda}$$

where

D_i = major dimension of the instrument aperture or the proximity distance if the former is not known.

3.6 When the instrument is used at distances from the source greater than R_i, it will not perturb the field in which it is placed if its impedance is of the order of the wave impedance.

In effect, this requires that if detector dipoles are used, these should be shorter than approximately $\frac{\lambda}{3}$ and of small diameter.

A secondary benefit of dipoles of this length is that the curvature of the fields will not introduce an error.

3.7 On the other hand, the use of excessively short dipoles or other means of achieving high sensor impedance may introduce errors in the reactive region. However, in this case, the error results in an indication which is always higher than the actual value.

In view of the foregoing difficulties, calibration of the measuring instrument is carried out best in the far field even though the instrument may actually be used in the reactive field region. As a consequence, the measuring instrument, regardless of the detailed nature of its sensors, will be calibrated in units of power density, usually in milliwatts per square centimetre (mW/cm^2).

4. CHARACTERISTICS OF THE MEASURING INSTRUMENT

4.1 Since levels which constitute a hazard will be established in other publications, instrumentation specifications shall be derived from those requirements.

While it might be desirable to specify sensor impedance as described above, not enough is known about this subject to do so. A fully rigorous specification cannot be prepared at this time.

4.2 Practical and significant specifications should at least include the following parameters:

a) Maximum dimension of the aperture in cm;

b) Effective aperture in cm^2, or proximity distance in cm (*see* Note 1);

c) Linearity;

d) Measurement range, expressed in mW/cm^2 (*see* Note 2);

e) Frequency response (*see* Note 3);

f) Error when the measuring instrument is held by hand;

g) Accuracy (expressed in decibels) (*see* Note 4);

h) Error caused by stray rf pick-up;

j) Response time (*see* Note 5); and

k) Directional characteristics.

NOTE 1 — Where it is possible to verify the effective aperture by calibration, it should be specified. When the effective aperture cannot be verified, the proximity distance, which is not rigorously related to the effective aperture but at least approximately establishes its magnitude, should be given.

NOTE 2 — To avoid its accidental destruction, the measuring instrument must be able, by the use of switches or other calibrated means, to withstand leakage density several times the statutory level and to measure down to about 10 percent of that level, with an accuracy as described below (*see* Note 4).

NOTE 3 — The measuring instrument shall be specifically calibrated for use at the frequency at which leakage is suspected or shall have known calibration characteristics *versus* frequency so that observed values may be standardized to defined units of measurement. The spacer tip shall not change the calibration by more than 0·25 dB or the sensor should be calibrated with the spacer tip permanently fixed to it.

NOTE 4 — For all readings from 25 percent of full scale indication to full scale indication, the error should be less than the stated value (usually 0·5 dB).

NOTE 5 — To search for zones of high leakage, the inherent response time of the sensor shall be sufficiently long (for example, one-half second) so that it will average semi-pulse waveforms appropriately. In addition, a longer response time (usually 3 seconds) may be available in the instrument by switch for use in making averaged measurements.

5. CALIBRATION OF INSTRUMENTS

5.1 The Calibration Source

5.1.1 *The Monopole System* — The measuring instrument should be calibrated in a known field where there is little likelihood of perturbation by introduction of the instrument or of the observer. To ensure the validity of the calibration, the field from the source should preferably be unperturbed by reflections from fixed installations.

A radiation source which has been found to be ideally suited to this calibration procedure is a $\frac{\lambda}{4}$ monopole which peers through an extensive metallic ground plane (3λ to $5\lambda \times 3\lambda$ to 5λ). The monopole is preferably located in a space which includes no structures for a distance of 100λ in any direction. The monopole should be fed from a suitable coaxial line from the underside of the ground plane.

The diameter and length of the monopole should be adjusted so that the monopole is resonant and matched at the frequency of interest. The power into the radiating element is measured by means of a directional coupler and a power meter.

The calibration system is shown in block diagram form in Fig. 1. The power source must include some provision for varying the output level so as to permit measurement of linearity. Frequency should be variable if calibration is to be done over a stated frequency band.

It is often convenient to include a gimballed mount or clamp made from polystyrene foam or other suitable non-metallic material of low dielectric constant to fix the sensor. The design should permit the sensor to be moved through 180° of elevation angle on two orthogonal axes, while maintaining source-sensor range constant.

NOTE — Use of calibrated horn is a suitable alternative.

5.2 Calibration of Proximity Distance — The sensor to be calibrated should be placed at a stated distance from the monopole greater than λ and less than the minimum dimension of the ground plane.

Connections from the sensor to the indicator should be positioned to lead straight away from the monopole radiator so as to minimize field perturbation by the measuring instrument and its leads. The senior should be oriented for maximum power reading.

5.2.1 *Two-Meter System* — Power input to the monopole is adjusted to provide approximately a three-fourth full scale indication on the meter when the gimbals are adjusted to hold the sensor at about 30° elevation above the ground plane. A second identical and identically oriented sensor is made to approach the first from either side and above and below, while maintaining the same distance. The approach should continue until either the two sensors are in contact or the indication of the first measuring instrument has changed by 2 dB.

The separation between the sensors, when this condition is achieved, should be measured in each quadrant. The largest value so obtained, in terms of the centre spacing between the two sensors, is the proximity distance.

NOTE — With reference to the definition of proximity distance, it is to be noted that when there is more than one distance at which the ± 2 dB [*see* **2.6** of IS:6134 (Part I)-1978*] change occurs, the greatest distance is the proximity distance.

5.2.2 *One-Meter System* — Since the field above a ground plane from a resonant monopole is very nearly constant (relative to 2 dB) in the first

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*Methods of measurements of electrical characteristics of microwave tubes: Part I Common to all microwave tubes.

30° of elevation angle, the ground plane can be used as a mirror to determine proximity distance. In this situation, the sensor is caused to approach the ground plane along a spherical surface while maintaining a fixed sensor orientation to the centre of this sphere until the 2 dB change in reading is noted.

All possible orientations of the sensor relative to the ground plane shall be measured after a 2 dB change regardless of the initial change in sensitivity. The proximity distance shall be twice the largest measured value from the centre line of the sensor to the ground plane.

5.3 Linearity — With the measuring instrument held as in **5.2** the input power to the antenna is increased slowly so as to note indicated power density at several stated values of radiated power. Excursions through the power range should be repeated in ascending and descending power until repeatable readings are obtained at each stated level of power. This could minimize possibility of errors due to meter problems (stickiness, hysteresis, etc) and would ensure that an accurate value of power density has been obtained at each stated power level.

5.3.1 The data should be plotted in suitable coordinates so that the resultant plot would be a straight line if the data were fully linear. Two curves should be drawn:

a) one consisting of a series of straight segment passing from adjacent point to adjacent point, and
b) the best fit straight line.

The maximum deviation between these curves should be within the linearity limits.

5.4 Sensitivity Calibration — (*See* Note 1 of **6**). With the instrument mounted as in **5.2** the sensor oriented for maximum power and the elevation angle adjusted so that the instrument axis is one proximity distance above the ground plane, adjust the sensor distance from the monopole to a stated value between λ and 3λ. Then adjust the frequency to mid-band and the input power to obtain full scale indication, thereafter holding both constant. Increase the elevation angle through several stated values relative to the antenna axis (usually 75°, 60°, 45°, 30°, 0°, −30°, −45°, −60°, −75°) and record the corresponding meter readings. Then repeat the measurements at the same incremented elevation angles for the orthogonal elevation axis.

Thus, for each elevation angle above the ground plane, four data points have been obtained. These four values are averaged and corrected for linearity using the calibration non-smooth curve (a) of **5.3.1.** The corrected values are used to integrate arithmetically the power density over the area of the stated hemisphere. The power value obtained from this integration, P_c, is related to the instrument correction factor by K.

$$K = P_{\text{radiated}}/P_c$$

Actual power density thus becomes indicated density multiplied by this factor.

5.5 Calibration at Various Frequencies — (*See* Note 1 of 6). The steps of **5.4** are to be repeated in full for frequencies at both ends of any band for which calibration is to be carried out.

5.6 Calibration Error when the Instrument is Held by Hand — When the instrument is placed at a fixed position in a steady far field of magnitude such as to produce approximately a full scale deflection of the meter, there shall be less than 1 dB difference in indication when:

a) the instrument is held in the normal manner (hand or otherwise), and

b) supported on a sufficiently large polyethylene foam plane.

5.7 Determination of Effective Aperture of the Sensor — The measuring instrument is mounted as in **5.4** and the source is adjusted to provide a stated known power density at the sensor. The detector (*see* Note) is removed from the sensor (with the sensor remaining in the same position). The actual power absorbed by the sensor is then measured by a power meter whose input impedance is identical to that of the detector. Dividing the measured power by the stated power density gives the effective aperture of the sensor in square centimetres.

NOTE — In some measuring instruments sensor and detector are integrally connected. In such cases the effective aperture shall not be measured.

5.8 Maximum Dimension of the Aperture of the Sensor — The physical length of the longest element of the antenna is measured directly or determined from an X-ray picture of the sensor. Materials which dielectrically load the sensor must be included, but non-participating materials can be excluded.

5.9 Calibration Accuracy — The calibration error is the maximum value of the sum of the absolute values of the linearity error (*see* **5.3**) expressed in decibels and the worst case correction factor *K* (*see* **5.4** and **5.5**) expressed in decibels.

5.10 Determination of Calibration Inaccuracy Arising from Stray RF Pick-up

NOTE — Measuring instruments which detect leakage power by a sensor which is remote from the indicators generally shall have less difficulties from proximity effects than those which combine indicator and sensor in an integrated arrangement. In either case, it is possible that a portion of the indicated value is derived from unintended coupling to the instrument or cable. Since the effect of such coupling shall vary with the spatial distribution of the field being measured, the error introduced by such unintended coupling cannot be calibrated out. As a consequence, a test for unintended leakage is important. When the meter is separate from the sensor, it is often necessary to cover connecting cables with lossy materials and to ensure that all openings are shielded or screened.

The field over a large surface area of polyethylene foam (or equivalent material of dielectric susceptibility approaching zero) is explored and marked on the surface a constant power density profile. Then, the sensor is position in the normal manner at one end of the sector marked out.

Then the meter box is so positioned that all its surfaces, in turn, are parallel to the constant power profile and at least 30 cm from the sensor. Likewise, all cables, line cords needed in normal use, etc, are exposed at the same distance. Under no condition the indicated value shall be changed by more than 1 dB.

5.10.1 *Precaution* — This measurement cannot be made too close to the source monopole as reflections from the meter box may effect fields at the sensor.

5.11 Determination of Response Time — The sensor is mounted as in **5.4**. The power source is adjusted to give full scale indication on the measuring instrument and the source power is measured calorimetrically. Then the power source is switched to pulse operation with nominally 10 percent duty factor. The pulse duration is increased gradually maintaining the average power constant as determined calorimetrically by the water load. The indicated power density will increase as the pulse duration increases until, at some pulse duration, the indicated value is the stated portion of the true value (as determined by the calorimeter). This value of the pulse duration, in seconds, is the response time.

6. MEASUREMENT OF MICROWAVE LEAKAGE

The tube whose leakage is to be measured shall be operated within the stated enclosure at the stated conditions and a suitably calibrated sensor shall, at the stated distance (*see* Note 1) from it, explore all the surface of the enclosure. Where indications of microwave power are observed, the sensor shall be rotated in all planes so as to maximize the indicated value when a specified meter time constant is used. The result of the measurement is the maximum of all the values so obtained (*see* Note 2).

Note 1 — To ensure uniformity of distance from the enclosure and for ease in searching, the sensor or the measuring instrument may be provided with a spherical tip with the sensor at its centre, whose radius is the stated distance for measurement. If such a positioning sphere is to be used, the calibration specified in **5.4** and **5.5** should be made with the sphere in place.

Note 2 — When the operating conditions include modulation of some form at such low frequency rates that the meter indication drifts or fluctuates, the average value should be used. The mean of the minimum and maximum values is often used as a suitable average.

NOTE 3 — The description of these measurement methods has been found necessary since earlier measuring instruments contribute to serious distortion of the leakage field and produce serious errors of measurement. The problem has become important because many microwave tubes operate with grounded anodes and allow direct access by operating personnel to these regions where microwave leakage may be hazardous.

6.1 Precaution — The presence of an operator or of the instrumentation may have an influence on the leakages and therefore on the measurement itself.

7. RADIO INTERFERENCE SHIELDING (MICROWAVE TUBES)

7.1 The method of radio interference shielding is given in Appendix A for information.

APPENDIX A

(*Clause* 7.1)

RADIO INTERFERENCE SHIELDING (MICROWAVE TUBES)

A-1. PURPOSE

A-1.1 The purpose of this test is to determine the amount of rf radiation from the tube and the susceptibility of a tube to external rf fields. This test will normally be conducted in a system in its final configuration and not on a tube alone.

A-2. METHOD A (SHIELDING TO PREVENT RADIATION)

A-2.1 Test Circuit — The test circuit is as given in Fig. 2.

A-2.2 Procedure — With the switch in position 1 the tube is operated with an input signal level of the specified value over the specified bandwidth, and with the output terminated into a matched load, the leakage power density at a distance of 1 meter from the tube shall be less than the specified value for all tube orientations. Switch position 2 is used for calibration of the system.

A-2.3 Precautions — It is recommended the tube be measured in its specified operating environment or equivalent since the presence of surrounding material can affect the rf pattern of the horn.

A-3. METHOD B (SHIELDING AGAINST RF PICK-UP)

A-3.1 Test Circuit — The test circuit is as given in Fig. 3.

A-3.2 Procedure — With the tube immersed in a uniform field of specified watts per square meter of arbitary polarization and with the input terminated into a matched load, the signal appearing at the output of the test set shown in Fig. 3 shall not exceed the value specified. The test shall be performed at the given frequencies or over the specified frequency band.

The output of the swept oscillator is amplified and the power supplied to the radiating horn is measured. By use of the directional coupler and precision variable attenuator, the power supplied to the vertical plates of the oscilloscope can be adjusted for a certain deflection at a calibrated power level when the switch is in position 1. When the switch is in position 2, the output of the tube can be measured as a result of rf field for the horn.

A-4. METHOD C (SHIELDING TO PREVENT FEEDBACK)

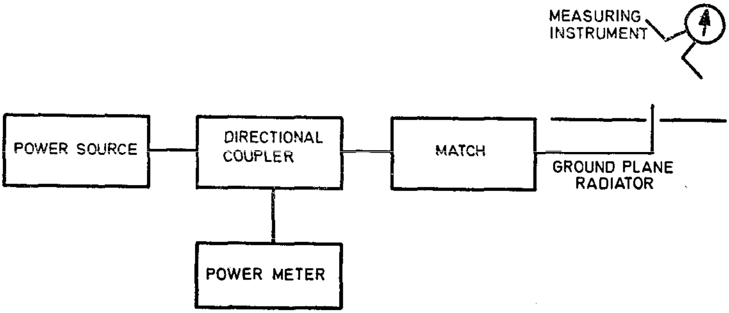
A-4.1 Test Circuit — The test circuit is as given in Fig. 4.

A-4.2 Procedure — The tube is connected as shown in Fig. 4 with normal voltages applied. The position of horn is 1 meter from the tube unless otherwise specified.

With the switch in position 1, the relative power output is noted. With the switch in position 2, the change in relative power output is noted. The change shall not be greater than the specified value.

A-4.3 Precaution — Since noise is used as an indicator from the tube, a band frequency limiter may be required to exclude signals of no interest.

Changes of power indication are a function of orientation of the horn. Unless otherwise specified, the orientation which produces the maximum change is found.



NOTE — The power source should have provision to vary power over more than a 10 dB range. In addition, measurement of the instrument response must be made (*see* **A-2.1.1**).

FIG. 1 BLOCK DIAGRAM OF CALIBRATION SYSTEM

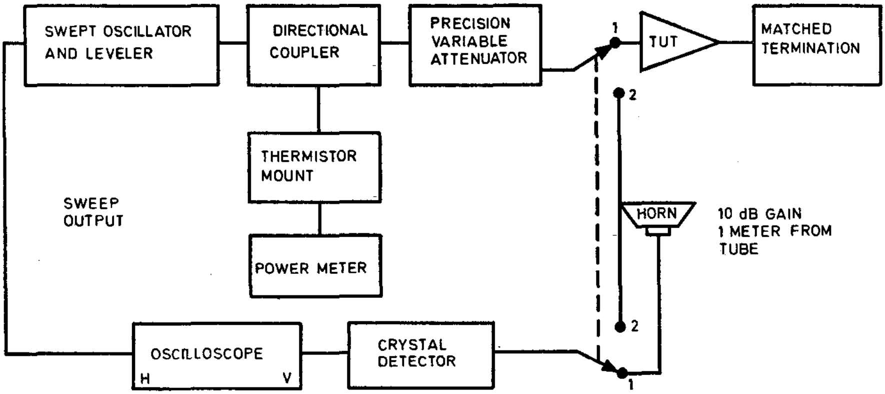


FIG. 2 SHIELDING TO PREVENT RADIATION

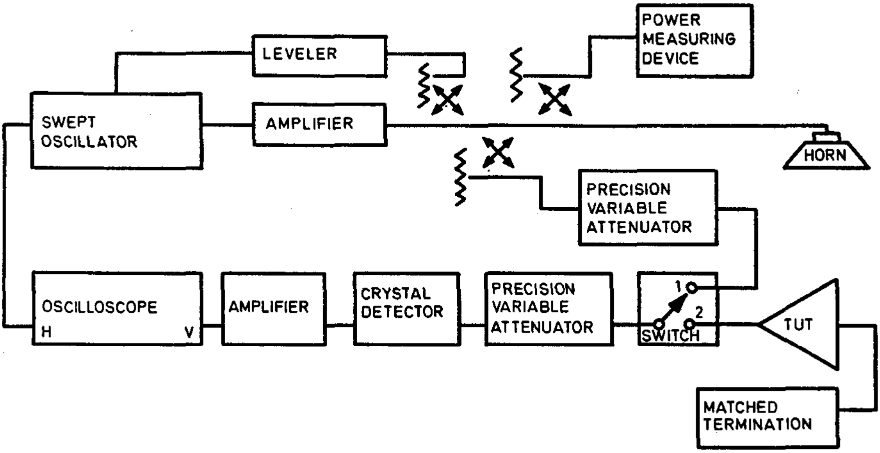


FIG. 3 SHIELDING AGAINST RF PICK-UP

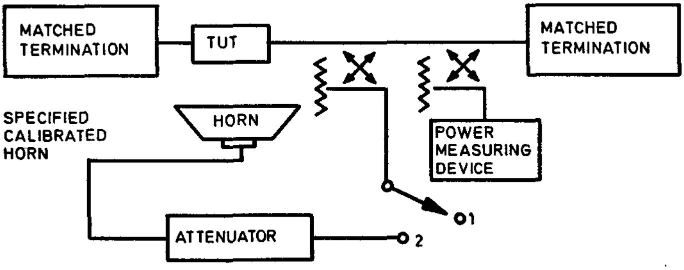


FIG. 4 SHIELDING TO PREVENT FEEDBACK

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IS:

1885 (Part IV/Sec 1)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 1 Common terms (*first revision*)

1885 (Part IV/Sec 2)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 2 X-ray tubes (*first revision*)

1885 (Part IV/Sec 3)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes

1885 (Part IV/Sec 4)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 4 Cathode ray tubes

1885 (Part IV/Sec 5)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 5 Pulse terms

1885 (Part IV/Sec 6)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 6 Noise in microwave tubes

1885 (Part IV/Sec 7)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 7 Camera tubes

1885 (Part IV/Sec 8)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 8 Photosensitive devices

2032 (Part IX)-1969 Graphical symbols used in electrotechnology: Part IX Electron tubes (other than microwave tubes)

2032 (Part XIII)-1971 Graphical symbols used in electrotechnology: Part XIII Microwave tubes

2597 (Part I)-1964 Code of practice for the use of electron tubes: Part I Commercial receiving tubes

2597 (Part II)-1967 Code of practice for use of electron tubes: Part II Special quality receiving tubes

2597 (Part III)-1969 Code of practice for the use of electron tubes: Part III Transmitting and industrial tubes

2597 (Part IV)-1970 Code of practice for the use of electron tubes: Part IV Cathode ray tubes

2597 (Part V)-1971 Code of practice for the use of electron tubes: Part V Rectifiers and thyratrons

2612-1965 Recommendation for type approval and sampling procedure for electronic components

2684 (Part I)-1972 Dimensions of electron tubes: Part I Miniature '9-pin noval' type (*first revision*)

2684 (Part II)-1972 Dimensions of electron tubes: Part II Miniature '7-pin type' (*first revision*)

2684 (Part III)-1971 Dimensions of electron tubes: Part III Octal base type

2684 (Part IV)-1971 Dimensions of electron tubes: Part IV Magnoval base type

2684 (Part V)-1972 Dimensions of electron tubes: Part V Local base type

3154-1965 Specification for X-ray tubes, diagnostic type

4096-1973 Method of measurement of optical focal spot size of X-ray tubes (*first revision*)

4147-1967 Method of measurements on conventional receiving electron tubes

4579-1968 Method of measurements on television picture tubes

4697-1968 Method of measurements on Geiger Muller counter tubes

5323-1969 Letter symbols and abbreviations for electron tubes

5627-1970 Methods of measurements on cathode-ray display tubes

5840 (Part I)-1970 Dimensions of cathode-ray tubes: Part I Tube outlines

5840 (Part II)-1970 Dimensions of cathode-ray tubes: Part II Bases

5840 (Part III)-1970 Dimensions of cathode-ray tubes: Part III EHT Terminals

6134 (Part I)-1978 Methods of measurements on microwave tubes: Part I Common to all microwave tubes [Superseding IS:6134 (Part I/Sec 1)-1971 and IS:6134 (Part I/Sec 2)-1972]

6134 (Part II)-1973 Methods of measurement on microwave tubes: Part II Oscilator tubes

6134 (Part III)-1973 Methods of measurement on microwave tubes: Part III Amplifier tubes

6134 (Part IV)-1977 Methods of measurement on microwave tubes: Part IV Magnetrons

6136-1971 Basic requirements for cathode-ray tubes

6214-1971 Phosphors for cathode-ray tube

6567-1972 Radiation protection for an X-ray tube in a protective tube-housing, operating between 10 kV and 400 kV

6568-1972 Implosion protection for TV picture tubes

6576-1972 Methods of measurements on gas filled cold cathode indicator tubes

6577-1972 Methods of measurements on gas filled cold cathode voltage stabilizing and voltage reference tubes

6757-1972 Dimensions for high tension cable terminations for X-ray tubes

6758-1972 Dimensions for high tension receptacles for X-ray tubes

7012-1973 Specification for X-ray tube shield

7144-1973 Methods of measurements on camera tubes

7146 (Part I)-1973 Methods of measurements on photosensitive devices: Part I Basic considerations

7146 (Part II)-1974 Methods of measurements on photosensitive devices: Part II Photo-tubes

7146 (Part III)-1974 Methods of measurements of photosensitive devices: Part III Photoconductive cells for use in the visible spectrum

7146 (Part IV)-1974 Methods of measurements on photosensitive devices: Part IV Photomultipliers

8319 (Part I)-1977 Dimensions of indicator tubes: Part I Tube type 1

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8319 (Part III)-1973 Dimensions of indicator tubes: Part III Tube type 3

8319 (Part IV)-1979 Dimensions of indicator tubes: Part IV Tube type 4